

What is claimed is:

1. A flow cell for examining specimen fluid flowing with sheath fluid,
comprising:

5 a housing defining a hollow fluid passage that includes an injection point, a geometric focusing portion in which the fluid passage narrows in a cross section dimension thereof, and an examination area;

a cannula having an output end disposed at the injection point in the fluid passage;

a first direct flow control pump for pumping the sheath fluid through the fluid passage such that the sheath fluid has a first known velocity at the injection point;

10 a second direct flow control pump for pumping the specimen fluid through the cannula such that the specimen fluid is injected into the fluid passage by the cannula output end as a stream of the specimen fluid having a second known velocity at the injection point, wherein the second known velocity is different from the first known velocity; and

a measurement device for measuring a parameter of the specimen fluid stream
15 passing through the examination area;

wherein a cross section dimension of the specimen fluid stream is focused by the sheath fluid via linear flow rate focusing and by the narrowing geometric focusing portion of the fluid passage via geometric focusing.

20 2. The flow cell of claim 1, wherein:

the second known velocity is less than the first known velocity; and

the cross section dimension of the specimen fluid stream is focused down by the sheath fluid via linear flow rate focusing.

25 3. The flow cell of claim 1, wherein:

the hollow fluid passage includes a top wall and a bottom wall that define the cross section dimension of the fluid passage therebetween; and

a portion of the bottom wall slopes toward the top wall to cause the narrowing of the cross section dimension of the geometric focusing portion of the fluid passage.

4. The flow cell of claim 1, wherein:
the hollow fluid passage includes a top wall and a bottom wall that define the cross
section dimension of the fluid passage therebetween; and
5 portions of the top and bottom walls slope toward each other to cause the narrowing
of the cross section dimension of the geometric focusing portion of the fluid passage.

5. The flow cell of claim 1, wherein the cross section dimension of the fluid
passage at the examination area is less than the cross section dimension of the fluid passage
10 at the injection point.

6. The flow cell of claim 1, wherein at the injection point, the cross section
dimension of the specimen fluid stream is less than an orthogonal cross section dimension of
the specimen fluid stream.

15 7. The flow cell of claim 1, wherein the housing includes a port extending from
the fluid passage, and wherein the flow cell further includes:
a third pump for pumping air bubbles from the fluid passage via the port.

20 8. The flow cell of claim 1, wherein:
the cannula includes an input end for receiving the specimen fluid;
the cannula input end has a first cross-section area; and
the cannula output end has a second cross-section area that is smaller than the first
cross-section area.

25 9. The flow cell of claim 8, wherein:
the first cross-section area is substantially round in shape; and
the second cross-section area is substantially elliptical in shape.

10. The flow cell of claim 1, wherein the measurement device measures an optical parameter of the specimen fluid stream.

11. The flow cell of claim 1, wherein the optical measurement device includes an imager for capturing images of the specimen fluid stream passing through the examination area.

12. The flow cell of claim 11, wherein:
the housing includes a transparent portion adjacent the examination area; and
the imager includes a microscope and camera for capturing the images of the specimen fluid through the transparent portion of the housing.

13. The flow cell of claim 1, wherein:
the first direct flow control pump includes:
a compression tube for containing the sheath fluid;
a compression surface; and
a roller for incrementally compressing the compression tube against the compression surface to create a moving occlusion of the compression tube that pushes the sheath fluid through the compression tube at a known velocity.
the second direct flow control pump includes:
a compression tube for containing the specimen fluid;
a compression surface; and
a roller for incrementally compressing the compression tube against the compression surface to create a moving occlusion of the compression tube that pushes the specimen fluid through the compression tube at a known velocity.

14. A method of flowing specimen fluid and sheath fluid through a hollow fluid passage of a flow cell having an injection point, a geometric focusing portion in which the

fluid passage narrows in a cross section dimension thereof, and an examination area, the method comprising;

flowing the sheath fluid through the fluid passage such that the sheath fluid has a first known velocity at the injection point;

5 injecting the specimen fluid into the fluid passage at the injection point as a stream of the specimen fluid having a second known velocity, wherein the second known velocity is different from the first known velocity; and

measuring a parameter of the specimen fluid stream passing through the examination area;

10 wherein a cross section dimension of the specimen fluid stream is focused by the sheath fluid via linear flow rate focusing and by the narrowing geometric focusing portion of the fluid passage via geometric focusing.

15 15. The method of claim 14, wherein the injection of the specimen fluid is performed using a cannula having an input end for receiving the specimen fluid and an output end disposed at the injection point in the fluid passage for injecting the specimen fluid.

20 16. The method of claim 15, wherein:
the cannula input end has a first cross-section area; and
the cannula output end has a second cross-section area that is smaller than the first cross-section area.

25 17. The method of claim 16, wherein:
the first cross-section area is substantially round in shape; and
the second cross-section area is substantially elliptical in shape.

18. The method of claim 14, wherein:
the second velocity is less than the first velocity; and

the cross section dimension of the specimen fluid stream is focused down by the sheath fluid via linear flow rate focusing.

19. The method of claim 14, wherein:

5 the hollow fluid passage includes a top wall and a bottom wall that define the cross section dimension of the fluid passage therebetween; and

a portion of the bottom wall slopes toward the top wall to cause the narrowing of the cross section dimension of the geometric focusing portion of the fluid passage.

10 20. The method of claim 14, wherein:

the hollow fluid passage includes a top wall and a bottom wall that define the cross section dimension of the fluid passage therebetween; and

portions of the top and bottom walls slope toward each other to cause the narrowing of the cross section dimension of the geometric focusing portion of the fluid passage.

15 21. The method of claim 14, wherein the cross section dimension of the fluid passage at the examination area is less than the cross section dimension of the fluid passage at the injection point.

20 22. The method of claim 14, wherein at the injection point, the cross section dimension of the specimen fluid stream is less than an orthogonal cross section dimension of the specimen fluid stream.

23. The method of claim 14, further comprising:

25 withdrawing air bubble from the fluid passage.

24. The method of claim 14, wherein the measurement of the parameter includes measuring an optical parameter of the specimen fluid stream.

25. The method of claim 14, wherein the measurement of the parameter includes capturing images of the specimen fluid stream passing through the examination area.

26. A method of forming a cannula from a hollow tube having first and second
5 ends and a first cross-section shape, comprising:
cutting a hollow tube to a desired shape, wherein the cut tube has a first end and a
second end and a first cross-section shape;
inserting a first mandrel having a first thickness into the first end;
crushing the first end onto the first mandrel;
10 removing the first mandrel from the first end; and then
inserting a second mandrel having a second thickness into the first end, wherein the
second thickness is less than the first thickness;
crushing the first end onto the second mandrel; and
removing the second mandrel from the first end;
15 wherein after the crushings of the first end, the first end has a second cross-section
shape that is different from the first cross-section shape.

27. The method of claim 26, wherein:
the first cross-section shape is substantially circular; and
20 the second cross-section shape is substantially elliptical.

28. The method of claim 26, further comprising:
heating and cooling the first end before the insertion of the first mandrel into the first
end.
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